9

SEEING AND HEARING

Most of the animal kingdom relies on the senses of seeing and hearing to gather information about the environment. In fact, the very survival of most animals depends on seeing and hearing. Light and sound are the forms of energy to which eyes and ears respond.

KEY CONTENT

Describe and build instruments that produce and control light and sound and describe their operation.

Describe the characteristics and applications of the transmission and reflection of light and sound.

Describe the relationship between the characteristics of sound, the vibration properties of the source and the sound wave.

Explain how animals use their senses to detect and respond to their environments.

Describe how the ear works.

KEY QUESTIONS

How do you hear?

How can you make a loud sound with a string?

How is a didgeridoo played?

Why can't you stop a sneeze when pepper gets in your nose?

Why do your ears pop?

Why do elephants have such big ears?

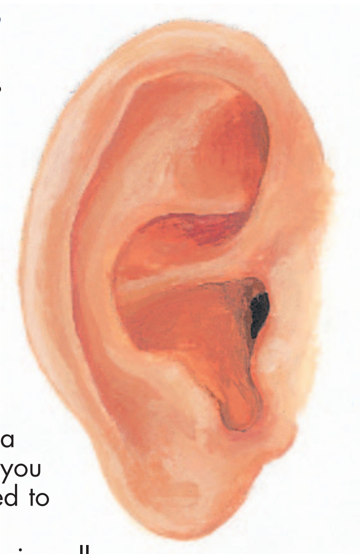
Are you the same as your mirror image?

How can bats see in the dark?

Thinking about *Seeing and hearing*

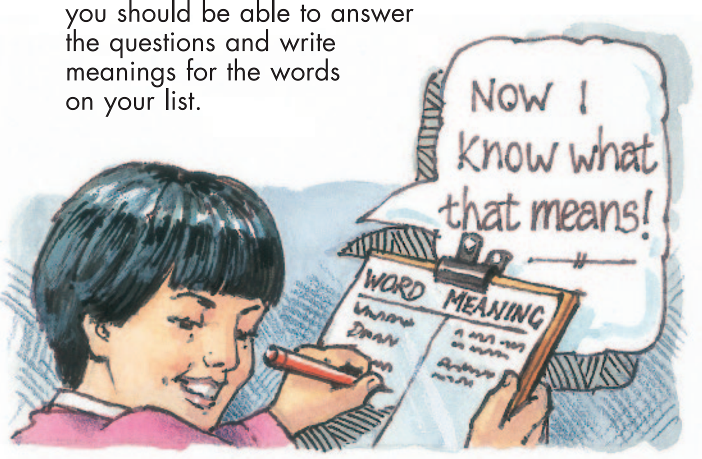
1. Eyes and ears

GROUP WORK You use your eyes and ears all the time. They help you to make sense of your world. Before you start this chapter, think about what you already know about your eyes and ears by completing the following exercises.



(a) With your group or partner, brainstorm a list of all the words you know that are related to your eyes and ears.
(b) Draw a mind map using all the words in your list. You can include additional words if new ideas arise while you are linking and connecting words. (See pages 232–4 if you need to refresh your memory about mind maps.)
(c) Once you have finished your mind map, take time to consider the following questions.
  (i) Which words do you feel really confident about?
  (ii) Which words do you feel less confident about? (That is, which words do you feel you need more information about to understand the concept well?)
(d) Compare your mind map with another group's, and then keep yours for reference as you learn more about your eyes and ears.
(e) Finish by listing all the questions that you would like to find answers for by the time you reach the end of this chapter.

By the time you have worked through this chapter, you should be able to answer the questions and write meanings for the words on your list.



2. Making sense of the world

List all of your senses. Choose one and write a report about how this sense works to help you survive.

3. Great inventions

GROUP WORK Scientists have made many new discoveries because new technologies have allowed them to see objects that are either very small or very distant.

(a) Name some technologies that have helped us to see, hear and understand more.
(b) Pick one example of a new technology and write a story reporting the discovery of this exciting new technology for a newspaper or journal. Make sure you include how you think it will help humankind. You can use your imagination in doing so, but make sure you include some facts about the technology.
(c) Find out something about the discoverer(s) of this new technology and how it was first received in the community.

4. Reflection on light

Many times each day we see our reflection in mirrors or shining surfaces. Work in pairs to answer the following questions:

(a) Think about how your reflection appears in a mirror then explain your thoughts about how this occurs to your partner.
(b) With your partner, make a list of everything that has to be present for your reflection to appear.
(c) Periscopes are used in submarines to see what is happening on the surface of the water. Explain how you think a periscope works.

5. Common sense

Keeping your eyes and ears in top condition is very important. What common dangers to eyes and ears do you come across every day? What can you do to protect these valuable sensory organs? Design a table to present your answers.

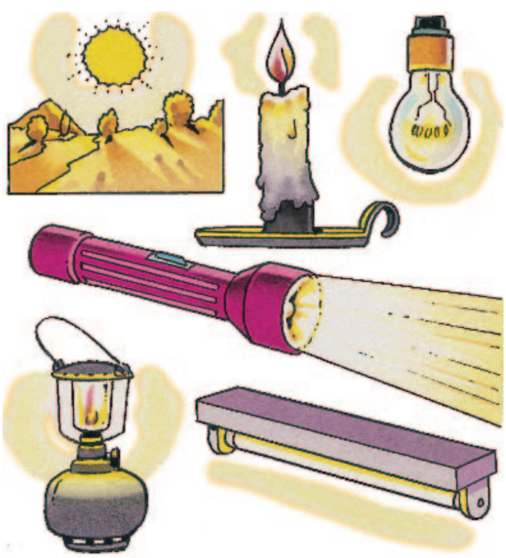
6. Energy transformations

(a) What do you think is meant by the term 'energy transformation'?
(b) Describe some forms of energy you already know about.
(c) Ask your friends or family what they think about when they use the word 'energy'.
(d) Explain how one form of energy may be transformed into another form of energy.

9.1 Out of the darkness

Without light from the sun, the world would be in darkness. Plants would not grow and all other life on Earth would not exist. Light is one of the forms of energy that come to us from the sun. It is a form of energy not needing a medium as it is able to travel through space (which is a vacuum) at about 300 000 km per second.

Objects or substances that give off their own light are said to be **luminous**. Examples of light sources are shown below.



Each of the light sources shown here is luminous.

Most of the light sources shown are **incandescent**. They emit light because they are hot. The sun, all other stars, light globes and flames are incandescent. Other sources, such as fluorescent tubes, the paint on the hands and numerals of clocks and watches, fireflies, glow-worms and some deep-sea fish, emit light without getting hot — they are not incandescent. Living things that emit light without heat are referred to as **bioluminescent**. An example is the angler fish.

Most things that you see are not luminous. They do not emit their own light. Light from luminous objects, such as the sun, light globes or fluorescent tubes, strikes them and is reflected into your eyes. The moon is not a luminous object. Its surface reflects light from the sun.

The angler fish, living in darkness about 4000 metres below the ocean surface, uses a luminous lure to attract its prey.

Experiment 9.1 Seeing the light

YOU WILL NEED
moderately dark room
torch or projector
well used chalk duster

- Shine the torch or projector onto a nearby wall.

1. What do you see on the wall?
2. Can you see the light beam between the light source and the wall?

- Now hit the chalk duster with your hand so that chalk dust falls between the light source and the wall.

3. Can you now see the light beam between the light source and the wall?
4. What happens to the light from the source to make it visible?

Experiment 9.2 Seeing things

YOU WILL NEED
a room that can be darkened

- Darken the room as much as you can.
- Concentrate on the darkest wall you can find and look carefully at the features that you can see.

1. Does the wall appear to be giving off light of its own?

- Now turn on the lights, open the curtains or blinds and look at the features of the wall again.

2. Can you see more or less detail when the room is well lit?
3. Where does the light that allows you to see the features of the wall come from?

Light beams are only visible when there are particles in the air to scatter the light into your eyes. The light beam from a street light can be seen if there is smoke or fog in the air.

How *light* travels

Although light cannot normally be seen as it passes through the air, conclusions can be formed about how it travels. For example, light travels in straight lines.

If light did not travel in straight lines, shadows would not be the same shape as the objects that make them. The experiment on the right shows that shadows can be fuzzy or sharp.

The darkest part of a shadow is called the **umbra**. The lighter part on the outside of the shadow is called the **penumbra**. In a dark room, the umbra gets no light from the light source. The penumbra does get some light from the source. As the light source gets smaller or further away, the penumbra gets smaller and the shadow gets sharper.

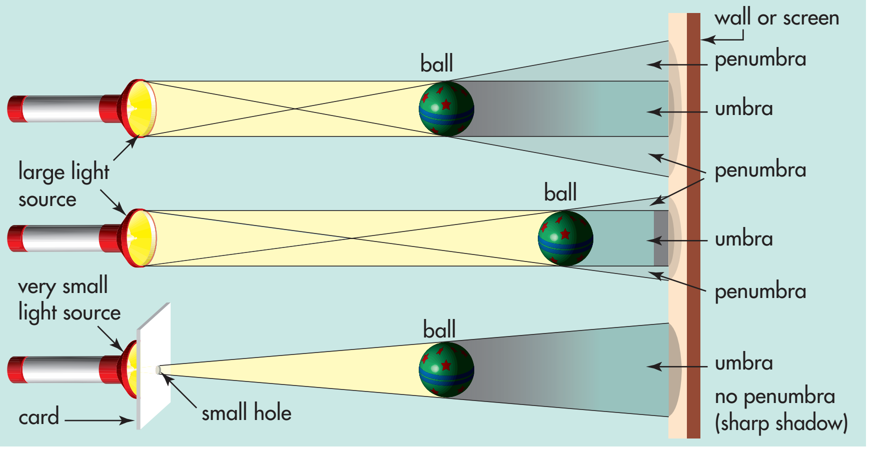
Experiment 9.3 CASTING SHADOWS

YOU WILL NEED

moderately dark room
candle and matches or torch
white card for screen

- Hold your screen vertically about 60 cm from your light source. Place your hand about midway between the light source and screen so that it makes a shadow on the screen.
- Observe the shadow as you move your hand closer to the light source.

1. How does the size of the shadow change?
2. Describe any other changes in the shadow.
3. Draw a simple diagram to explain why the shadow changes.



Shadows can be fuzzy. They often have two parts — the umbra and penumbra.

Experiment 9.4 JUST CHECKING

YOU WILL NEED

small length of rubber tubing or hose
candle and matches or a torch

- Look at the small light source through a straight piece of rubber tubing. Now bend the tubing slightly.

1. Can you still see the light source?
2. Does this observation support the idea that light travels in straight lines?
3. Draw a diagram to show why you are unable to see the light source through the bent tubing.

Activities

Remember

1. What is light and how fast does it travel through space?
2. (a) What does 'incandescent' mean?
   (b) List two examples of light sources that are incandescent.
   (c) List two examples of light sources that are not incandescent.
3. Why do you see the beam of light from a torch if it is foggy?
4. Outline some evidence that supports the conclusion that light travels in straight lines.

Think

1. Which of the following objects are luminous?
   (a) the sun
   (b) the moon
   (c) the stars
   (d) a burning candle
   (e) this page
2. Which of the following objects are incandescent?
   (a) the sun
   (b) a firefly
   (c) a burning match
   (d) a glowing fluorescent tube
3. Explain how it is that you can see this page even though it does not emit light of its own.
4. Explain, with the aid of diagrams, why shadows are sometimes fuzzy and sometimes sharp.
5. The speed of light is 300 000 kilometres per second. How long does it take light to travel from the sun to the distant planet Pluto when it is 6000 million kilometres from the sun?

Investigate

Find out more about animals that are bioluminescent.

9.2 Reflections

What does this person really look like?

When you look in a mirror you see an **image** of yourself. If the mirror is a plane, or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange, like the one in the photograph on the left.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Images can also be formed when light is reflected from other smooth surfaces, such as a lake.

An image on still water. How can you tell that the photograph is not upside down?

Experiment 9.5 LOOKING AT IMAGES

YOU WILL NEED

plane mirror

shiny tablespoon or soup spoon

- Look at the image of your face in a plane mirror. Wink your right eye.

1. Which eye in your image appears to wink?

- Write the word 'IMAGE' on a piece of paper and place it in front of the mirror so that the word faces the mirror.

2. Which letters in the image look different? Which letters look the same?

- Write down how you think an image of the word 'REFLECTION' will look in the mirror. Test your hypothesis.

3. Was your hypothesis correct?

- Look at your image on the back of a spoon. This surface is convex. Convex means 'curved outward'. Move the spoon closer to you and then further away.

4. How is your image on the convex side of the spoon different from your image in a plane mirror?
5. How does the size of the image change as you move further away from the curved surface? Does it change in any other way?

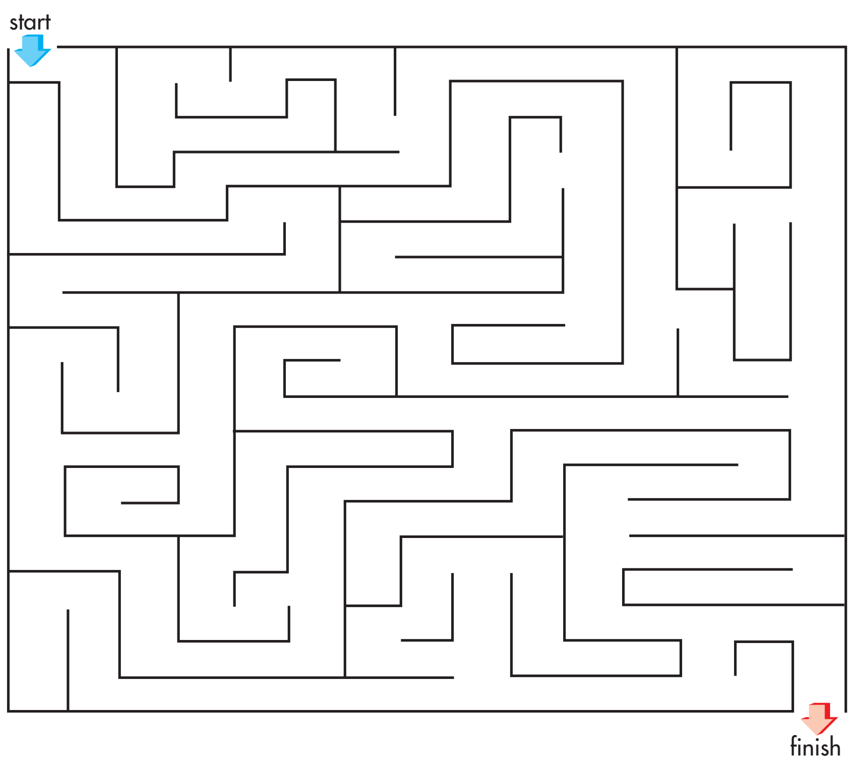
- Look at your image on the front of the spoon. This surface is concave. It is curved inward. Move the spoon as close to your eyes as you can, then further away.

6. How is your image on the concave side of the spoon different from your image in a plane mirror and on the other side of the spoon?
7. How does the image change as you move further away from the curved surface?
8. List some places where you have seen curved mirrors. State whether the mirrors are convex or concave and explain why they are used.

Experiment 9.6 A-MAZE-ING MIRRORS

YOU WILL NEED
plane mirror
copy of the maze below

- Place the maze flat in front of a mirror. Look at the image of the maze and use a pencil to follow the maze without crossing the lines. Do not look at the maze itself — only at its image in the mirror! If you don't trust yourself, have a friend hold a piece of card so that you can see only the image.



Can you complete the maze without crossing the lines, using its mirror image?

Lateral *inversion*

The sideways reversal of images that you see when you look at yourself in a mirror is called **lateral inversion**. The sign on the ambulance in the photograph is printed so that drivers in front of it can read the word 'AMBULANCE' easily in their rear-view mirrors.

Why is the word 'AMBULANCE' printed in reverse?

Activities

Remember

1. What does a mirror do to light in order to form an image?
2. In which type of mirror can your image be upside down?
3. How is your image in a plane mirror different from the real you?

Think

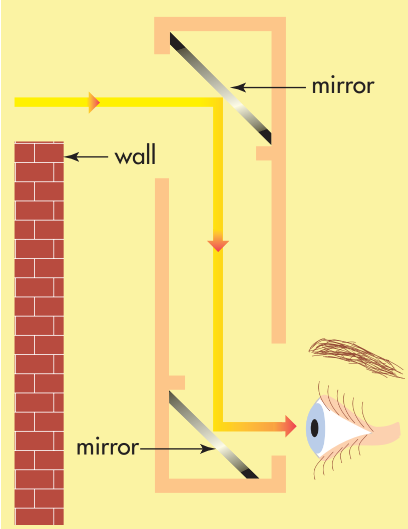
1. Why do dentists use concave mirrors to examine teeth?
2. Which type of mirror is used to help you see around corners?
3. How will the word 'TOYOTA' on the ambulance look in the rear-view mirror of the driver in front of it?

Investigate

Look up the laws of reflection. Design and carry out some simple experiments that demonstrate these laws.

Create

Design and build a simple periscope like the one shown below. You will need stiff card, scissors, two small mirrors, sticky tape or glue, a pencil and a ruler. Write an explanation of how it works using diagrams and real examples.



A periscope uses mirrors to enable you to see around corners or over objects.

9.3 Making sounds

Humans and other animals rely heavily on sound to communicate with each other. You can use your voice, whistle or tap something to make a sound. How else can you make a sound?

Good *vibrations*

All sounds are caused by **vibrations**. When you speak or sing, the vocal cords in your throat vibrate. You can feel the vibrations if you put your hand over the front of your throat. These vibrations cause the air in your throat and mouth to vibrate. The air around you then vibrates. The sound is heard by you or someone else when air surrounding you vibrates, in turn causing your eardrum to vibrate. The travelling vibration is called a **sound wave**. This sound wave is a form of energy that must have a medium in which to travel.

The highness or lowness of a sound is called its **pitch**. The more quickly an object vibrates, the higher the pitch of the sound it makes. A short string vibrates more quickly than a long one. It therefore has a higher pitch. When you blow across the top of a straw, the air inside it vibrates. If the straw is shorter, the air inside vibrates faster, producing a higher pitched sound.

Making it *louder*

If you pluck a stretched guitar string while it is not attached to a guitar, it vibrates but makes very little sound. If you strike a stretched drum skin while it is not attached to the drum, it makes very little noise. Even your own vocal cords make very little noise while they are vibrating. In each of these cases a vibration is needed to create the sound but an enclosed region of air is needed to make the sound louder.

Experiment 9.7 VIBRATIONS AND PITCH

YOU WILL NEED
ruler
2 straws
scissors
small beaker and large beaker
spatula

- Hold a ruler over the edge of a table so that one end is firmly pushed down. Flick the overhanging end of the ruler.
- Move the ruler so that more of it is over the edge of the table and flick it again.

1. How does the sound change as the vibrating part of the ruler is made longer?

- Cut one straw into two so that one part is twice as long as the other part. Place the top of the uncut straw lightly against your bottom lip and blow gently across the opening. Listen to the sound made.
- Blow across the two shorter pieces of straw in the same way and listen to the sounds.

2. How does the sound change as the straws get shorter?

- Tap the side of a small beaker gently with a spatula and listen to the sound. Do the same with a larger beaker.

3. How do the sounds compare?
4. How would you change each of the following to make a higher pitched sound?
   (a) the length of a vibrating strip of wood
   (b) the length of a tube of air
   (c) the size of a cymbal

Experiment 9.8 MAKING IT LOUDER

YOU WILL NEED
guitar
guitar string
tuning fork

- Pluck a stretched guitar string. Listen to the sound it makes.
- Pluck a similar string attached to a guitar.

1. How does the sound of a plucked string change when it is attached to a guitar?

- Strike a tuning fork on the sole of your shoe and listen to the sound it makes. While it is still vibrating, place its base on a solid table surface.

2. How does the sound change when the tuning fork is placed on the table?
3. Explain why the sound changes.

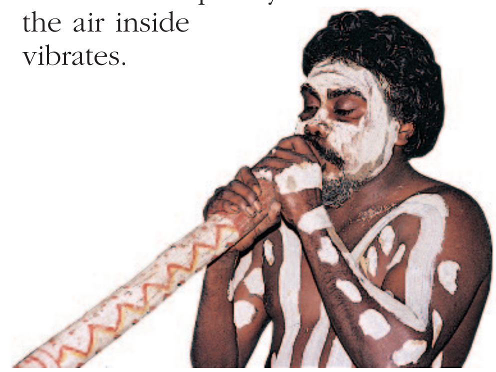
The air inside the body of an acoustic guitar is set vibrating by the strings. The air inside a drum vibrates when the drum skin is struck. The vibrating air inside your throat and mouth makes the sound created by your vocal cords loud enough to be heard.

The *sounds* of *music*

With an acoustic guitar, the vibrations are made by plucking the strings. The air around the sound hole vibrates, causing the air inside the body of the guitar to vibrate. In an electric guitar, a microphone or pick-up detects the vibrating air and converts it to electrical energy. An amplifier is then used to make the sound louder. The pitch of the sound made by a guitar is increased by shortening the strings using your fingers, tightening the strings or using lighter strings.

A saxophone's vibrations are first made by a thin wooden reed. The air inside the saxophone then vibrates, making a loud sound. The pitch can be changed by using keys to open or close holes. When all the holes are closed, the saxophone contains a long column of air, producing a low pitched sound. As holes are opened, the length of the air column becomes shorter and the pitch increases.

The didgeridoo has no holes to change the length of the column of vibrating air. The player blows into the instrument using loosely vibrating lips to control how quickly the air inside vibrates.



Activities

Remember

1. Explain how all sounds are made.
2. If you blow across the top of a straw, a sound is made. How could you increase the pitch of the sound?
3. Which vibrates more quickly — a long string or a short string made of the same material?
4. A plucked guitar string makes very little noise on its own. Why does it sound much louder when it is attached to a guitar?

Think

1. Explain how different notes are played on:
   (a) a single string of a guitar (b) a recorder (c) a xylophone.
2. How is the higher pitched note obtained on each of the three instruments in question 1?
3. Complete the gaps in the following table.

Musical instrument	What vibrates first?	What makes the sound louder?
guitar	plucked string	air inside guitar
trumpet	player's lips	
drum		air inside drum
saxophone		air inside saxophone
	string hit by hammers	air inside instrument

Create

Make a string telephone. You will need about 5 metres of string and two open and empty cans. Punch a small hole in the bottom of each can. Thread the string through each hole and tie a knot to keep the string in place. Hold the cans far enough apart so that the string is tight. Talk into the can at one end while your partner listens at the other end.

1. How does the sound travel from one can to the other?
2. Does the sound change if you make the string tighter or looser?
3. Would a string telephone work without the cans? Why are the cans used?

9.4 Getting the message

You remain aware of your environment and the changes that occur around you by using your senses. Your sense organs contain special cells called **receptors** that respond to stimuli. A **stimulus** is a feature of the environment that your body can detect. The table below shows how your senses respond to your environment.

Spreading *the message* around

The senses are just part of your body's communication system. The system:

- receives messages (stimuli) from the environment
- sends the messages to the brain (or sometimes directly to other parts of the body) through nerves
- interprets the messages and decides how to respond to them
- sends messages through nerves to other parts of the body, telling them how to respond.

All this happens very quickly. Your brain is capable of receiving, interpreting and sending out millions of messages each second. The messages travel through the nerves at speeds of about 100 metres per second.

Responses to messages that follow this entire pathway (shown below) are called **conscious responses**. They involve the brain and require some thinking. Packing up when you hear the school bell or siren at the end of a lesson is an example of a conscious response. The stimulus is the sound of the bell or siren.

Reflex *actions*

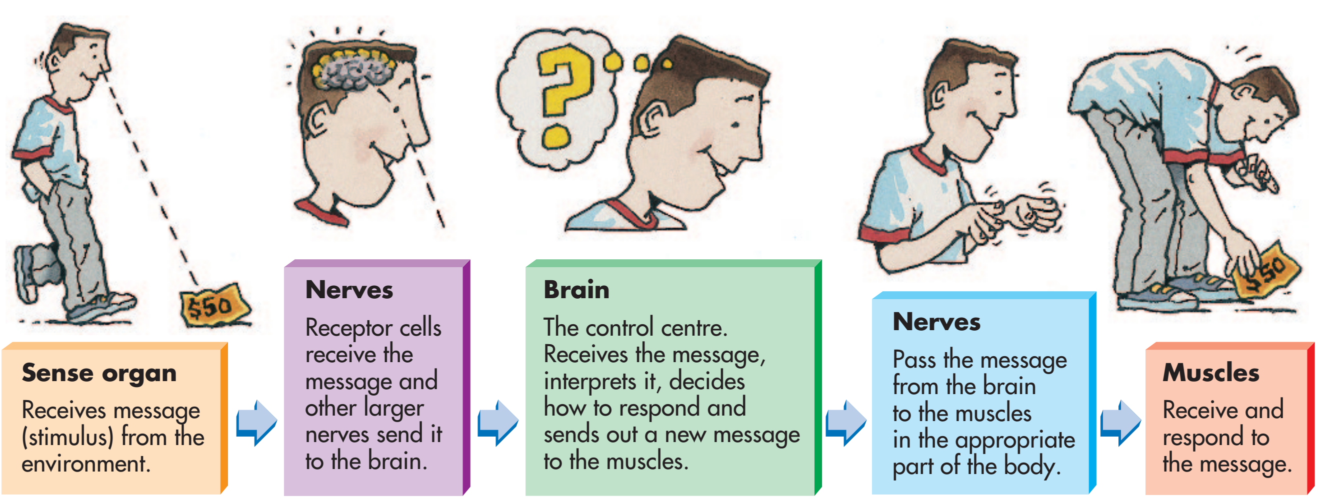
Sometimes a message bypasses the brain and goes from the receptors in the sense organ to the spinal cord and back to the muscles. The muscles respond very quickly because no thought is required. Responses that do not involve the brain are called **reflex actions**. Some examples of reflex actions are:

- sneezing when pepper gets in your nose
- pulling your hand back when you touch a hot object.

Can you think of some other examples?

Your senses

Sense	Sense organ	Receptors	Stimulus
sight	eye	special cells called cones and rods at the back of the eye	light
hearing	ear	hairs in the cochlea inside the ear	sound
touch	skin	separate receptors for each type of stimulus	heat, cold, light contact, pain, pressure, movement
taste	tongue	tastebuds	sweet, salty, bitter and sour substances
smell	nose	olfactory nerves inside nose	odours



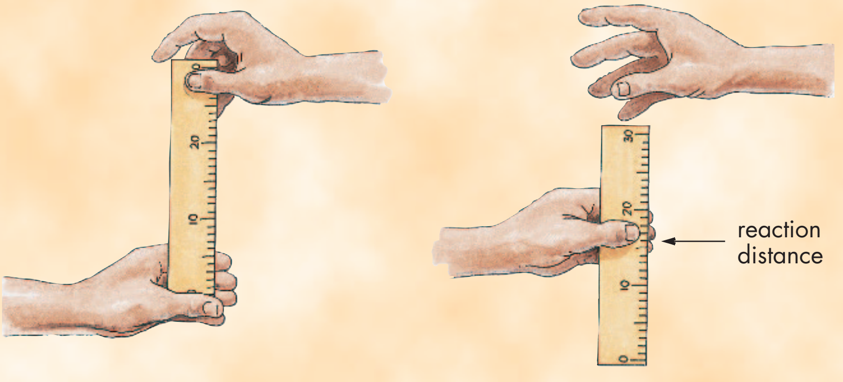
Your body's communication system

Experiment 9.9

HOW QUICKLY CAN YOU RESPOND TO A STIMULUS?

YOU WILL NEED
metre ruler

- Hold out the hand that you normally write with while your partner holds the metre ruler between your thumb and fingers without touching. Make sure that the top of your hand is at the 'zero' on the ruler and that your thumb and index finger are about 2 cm apart.
- When you are ready, ask your partner to drop the ruler soon. Your task is to catch the ruler as soon as you see your partner drop it.



Measuring reaction distance

- Record the reaction distance to the nearest centimetre in the table below.
- Repeat this procedure twice more, recording the reaction distance in the table.
- Calculate the average reaction distance.

1. What do you think would happen if you repeated the reaction distance test with your other hand? Will the average reaction distance be greater, the same or less? Write down your hypothesis, then test it.
2. Was your hypothesis supported by your results? If not, suggest why.

Reaction distance

	Reaction distance (cm)			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
writing hand				
other hand				

3. Which sense was used to detect the stimulus in this experiment?
4. Was catching the ruler a conscious response or a reflex action? Give a reason for your answer.
5. Why was it necessary to repeat the measurements three times for each hand?
6. If a friend suggested that it would have been better to repeat each test ten times to obtain a more accurate result, would you agree? Give a reason for your answer.

Activities

Remember

1. What is a receptor?
2. What is a stimulus?
3. Name the sense organ corresponding with each of the following stimuli: sourness; cold; perfume; light; sound.
4. What is the difference between a conscious response and a reflex action? Give one example of each.

Think

1. Complete the table below by indicating whether each event is a stimulus or a response.

Event	Stimulus or response
you pull your hand away from a hot cup	
the phone rings	
a dog barks at an intruder	
a traffic light turns green	
you shiver after getting out of a swimming pool	

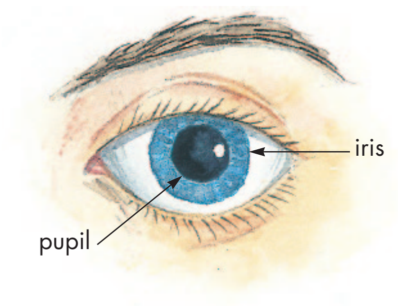
2. Write down whether each of the following is a conscious response or a reflex action:
   (a) stopping at a red traffic light
   (b) blinking when a bright light flashes unexpectedly in front of you
   (c) a dog's mouth watering when it sees food
   (d) answering the doorbell.
3. Suggest where the term 'knee-jerk reaction' might come from.

Investigate

Design your own investigation to find out if it is possible, with practice, to decrease the time taken between receiving and responding to a stimulus. You could use the technique for measuring reaction time described in the experiment on the left or devise your own method.

9.5 In the wink of an eye

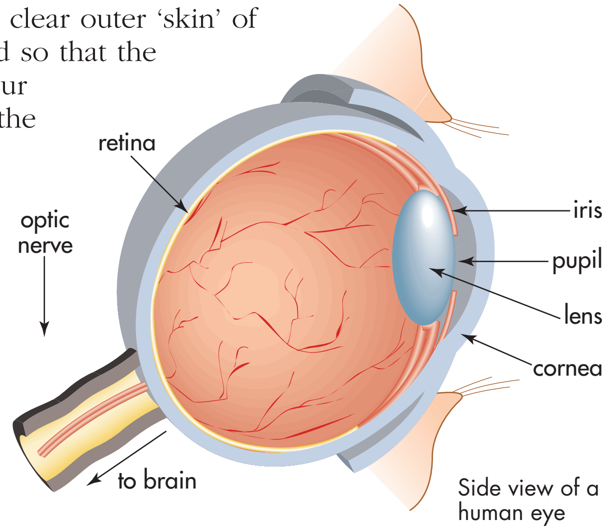
Most of the information that you gather about the world around you is obtained through the sense of sight. The eye allows you to receive the light that comes from luminous objects like the sun, electric lights and fire. If you could detect only objects that gave off their own light, you would not see very much! Your eyes also receive light which is reflected from non-luminous objects and substances. The walls of the classroom, for example, can be seen only because light from the sun or fluorescent tubes bounces off the walls. Some of that reflected light enters your eyes.



Close-up of a human eye

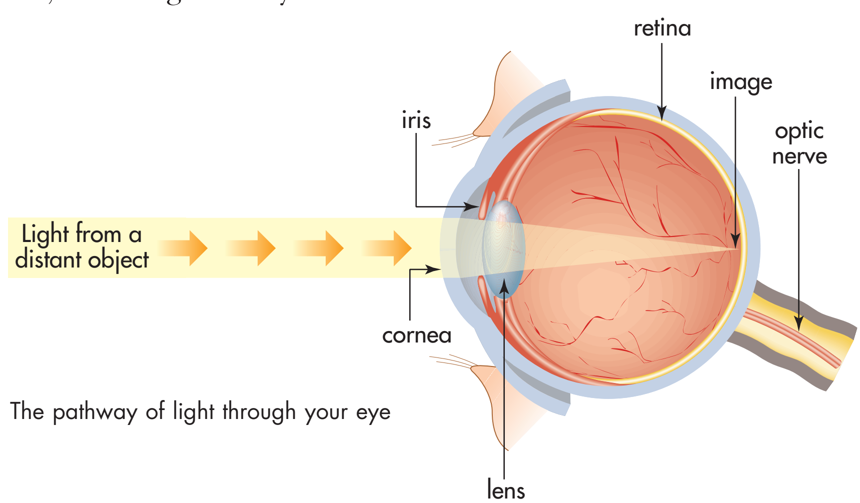
Some of the light that is reflected from the page you are now reading enters your eye through your **pupil**. The pupil is simply a hole in the **iris**. The iris is the colourful part of your eye. It is a ring of muscles that opens and closes to make the pupil large or small. If you are in a dark room, the pupil needs to be large so that as much light as possible can enter your eye. Outside on a sunny day, your pupil needs to be small so that not too much light gets in. The opening and closing of your iris is a reflex action, that is, you don't have to think about it.

The **cornea** is the clear outer 'skin' of your eye. It is curved so that the light approaching your eye is bent towards the pupil. The clear, jelly-like **lens** bends or focuses light onto the **retina**. The lens is connected to muscles which can make it thick or thin. This allows your retina to receive a sharp image of distant or nearby objects.



Side view of a human eye

Although your eye receives the light and produces an image of what you see, it is your brain that interprets and makes sense of the image. The receptors on the retina respond to the amount and colour of light by sending signals to the **optic nerve** which, in turn, sends signals to your brain.



The pathway of light through your eye

Experiment 9.10

IN THE DARK

- Cup your hands loosely over both eyes so that you cannot see anything but your hands. Keep your eyes open. Look at the insides of your hands.
- After about one minute, have your partner look carefully at your pupils and tell you what they observe.

1. What happens to the iris as the hand is removed?
2. Explain these observations.

Looking *after* your eyes

Your eyes are very important for detecting and responding to your environment so they must be treated with care. Your eyes have several natural protection devices. The cornea is kept clean by tears that are released every time you close your eyes. They keep the cornea clear of dust and other small particles that could damage it. Your eyebrows and eyelashes protect your eye from damage by water and small particles. Blinking is a reflex action that closes your eyes when they are threatened by a rapidly approaching object. When dust or other small particles get into your eye, it responds by releasing tears to wash them away.

You should not rub your eyes if foreign particles get into them. That could move the particles further in, making them more difficult to remove and increasing the damage to your eye. In the laboratory, if a substance does get into your eye, your teacher should be notified immediately.

There are many instances when extra protection is needed in the form of safety glasses. Your teacher will inform you when they need to be used in the science laboratory.

Experiment 9.11

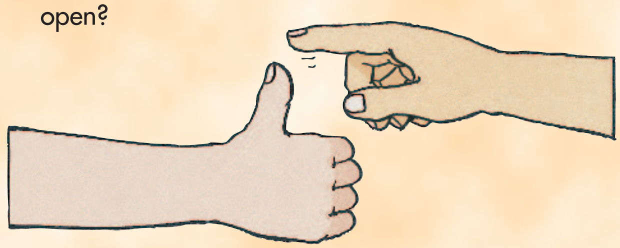
ARE TWO EYES BETTER THAN ONE?

- Stretch one arm out in front of you with your thumb up. Have your partner step back one arm's length from your thumb, close his or her right eye and try to touch the top of your thumb with one finger.
- Try it again with both eyes open.
- Try it again with the left eye closed instead.

1. Did your partner succeed with the left eye, right eye, neither or both?

- Now swap roles and try this yourself.
- Design a table of results for the whole class.
- Complete the table and use it to construct a bar graph to display the class results. The graph should help you reach a conclusion.

2. Is it easier to estimate distances with two eyes open?



Activities

Remember

1. Complete the table to describe and state the purpose of each of the main parts of the eye.

Parts of the eye

Part	Description	Purpose
cornea		
pupil		
		changes the size of the pupil
lens		
	'screen' at the back of the eye	

2. How does the information received by the eye get to your brain?
3. How does your eye naturally protect itself from damage by small particles?

Think

1. When you walk into a dark room at night you cannot see anything. A minute later, without any additional light, you can see. What behaviour of the eye allows this to happen?
2. Explain fully why it is necessary to wear safety glasses when performing heating experiments in the science laboratory. What should you do if a substance does get into your eye? What should you not do?

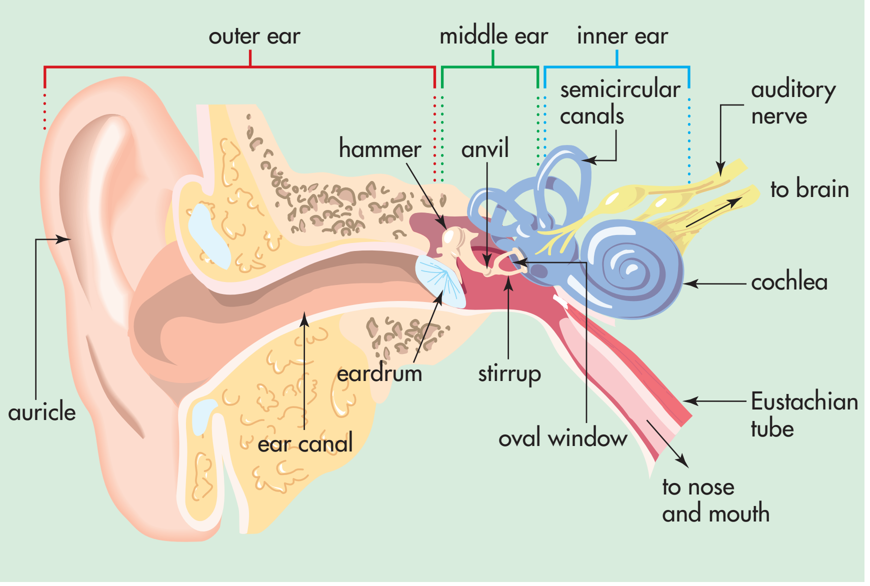
Imagine

Imagine that you are a beam of light coming from a torch. Describe your journey as you travel through the eye to the optic nerve and on to the brain.

Investigate

1. Find out why people blink. Do some people blink more than others? Why do you think this is so?
2. What is night blindness? What causes it? How can it be avoided?

9.6 What did you say?



When a sound is made, the surrounding air vibrates. Your ear detects the sound when the air inside the ear canal vibrates, causing the eardrum to vibrate at the same rate.

The ear can be divided into three main parts. They are the outer ear, the middle ear and the inner ear.

Outer ear

The outer ear funnels the air vibrations through the **ear canal** to the eardrum. The **eardrum** is a thin flap of skin, or **membrane**, that vibrates in response to the vibrating air particles. The fleshy, outer part of the ear is called the **auricle**.

Middle ear

The middle ear contains three small bones called the hammer, the anvil and the stirrup. These three tiny bones (known as the **ossicles**) pass on the vibrations to the inner ear through the **oval window**.

Inner ear

The inner ear contains the **cochlea** and the **semicircular canals**. The cochlea is a snail-shaped system of tubes full of fluid. When vibrations are passed through the oval window by the stirrup, the fluid moves tiny hairs inside the cochlea. These hairs are attached to the receptor nerve cells that send messages on their way to your brain through the **auditory nerve**. The semicircular canals also contain a fluid. However, they are not involved in hearing sound. When you move your head, the fluid in the semicircular canals moves hairs that send signals to the brain. The signals provide your brain with information to help you keep your balance.

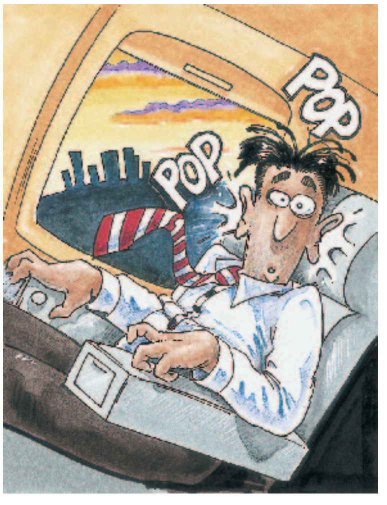
SCIFACTS

When you are landing or taking off in a plane, your ears 'pop'.

If you climb steeply, the air pressure inside your middle ear remains the same while the air pressure outside drops. The air inside pushes on the eardrum causing an uncomfortable feeling.

The 'popping' is caused as the Eustachian tube, which is normally closed, opens. This allows air to rush out of your middle ear to your nose and mouth. The pressure is then the same on both sides of the eardrum.

When you descend quickly the 'popping' occurs as the air rushes into your middle ear to balance the increasing pressure outside. If you swallow hard you can make the 'popping' happen sooner.



Looking *after* *your* ears

Your ears are very sensitive and need to be looked after. Your eardrum is very easily damaged. For this reason, you should never put anything in your ears.

The ear canal contains wax and tiny hairs which, together, trap dust and other small particles that could damage your eardrum. Sometimes the wax builds up and hardens, blocking up your ear canal. Never try to remove this wax yourself! Your doctor can remove it for you.

Loud noises can also damage your ears. This is especially a problem if you are exposed to loud noise for a long time.

The eardrum is easily damaged. Ear protection is needed when working with noisy machinery, such as racing cars.

Activities

Remember

1. Complete the table about the parts of the ear.

Part	Description	Purpose
eardrum		
	three small bones in the middle ear	
	an opening into the inner ear	to allow vibrations to pass into the cochlea
cochlea		contains receptor cells for hearing
		allows air to move between the middle ear and the mouth and nose

2. How does the information received by the ear get to your brain?
3. The semicircular canals in your ear are not involved in hearing. What is their purpose and how do they work?
4. How is the eardrum protected from damage through dust and other small particles?

Think

1. When you clap your hands a sound is heard. Explain how the sound gets from your hands, through the air and through your ear.
2. Two astronauts in space working outside the space shuttle are unable to hear each other, no matter how loudly they speak or even yell. Yet when they are inside the space shuttle with helmets on they can hear each other easily. Why is there a difference?
3. Why should you never try to remove ear wax yourself?

Investigate

Design an experiment to find out how well you can predict the direction from which the sound of a hand clap comes. You could extend your experiment to investigate:

- the effect of different types of sounds
- whether your ability to locate sounds is better inside or outside
- whether background noise makes it harder to locate sounds.

Perhaps you can suggest some other variables that you could investigate.

9.7

SCIENCE & technology

ENERGY TRANSFORMATIONS

Once scientists learnt how to transform sound, light and heat energy from one to another, it opened up the development of new technologies that improve our quality of life and allow us to explore our universe.

The planets Uranus, Neptune and Pluto could never have been discovered until the **telescope** was invented. The **organisms** that cause disease cannot be seen without the aid of a **microscope**. Telescopes and microscopes are just two devices that are used to extend the sense of sight.

The sense of hearing can be extended too. Doctors use stethoscopes to listen to your heartbeat. Hearing aids make sounds louder to assist people with some types of hearing impairment.

Extending *the* sense *of* sight

Lenses are used in microscopes, telescopes and binoculars to extend your sense of sight when objects are too small or too far away to see with your eyes. They are also used in spectacles to correct sight problems caused when images are not focused properly on the retina.

A magnifying glass can be used to make print on a page appear larger. It can also be used to focus sunlight into a point on a sheet of paper, which transforms light energy from the sun into heat energy. After a few moments, the point on the paper becomes hot and soon scorches the paper, which eventually bursts into flames. A glass bottle discarded in the bush can act like a magnifying glass, turning the sun's light energy into heat that can start a bushfire.

Binoculars act as magnifying glasses to bring the action closer.

Exploring *space*

Space probes and satellites extend our ability to gather information from deep space. The information they collect is beamed back to Earth in radio waves, which are collected by antennas and radio telescopes. A radio telescope is often called a 'dish', because it has a large curved dish to collect these signals. The signals are sent to a focus point above the dish, rather like a magnifying glass focusing the sun's light. After the radio signals have been concentrated, they are picked up by an antenna which turns them into electrical signals. These electrical signals are then fed into a computer which turns them into a picture.

The power of a radio telescope is limited by the size of its dish. To allow a radio telescope to gather finer detail and better quality data, astronomers combine dishes into an array. An array can be two or more dishes placed side by side or located on different parts of the Earth's surface. An array can gather radio waves as if it were one enormous dish, which increases greatly the amount and quality of information received.

Experiment 9.12

MAKING IT SEEM LARGER

YOU WILL NEED

hand lens or magnifying glass
small objects, such as leaves, shells, small insects in a jar, tissue paper, granite
sharp lead pencil

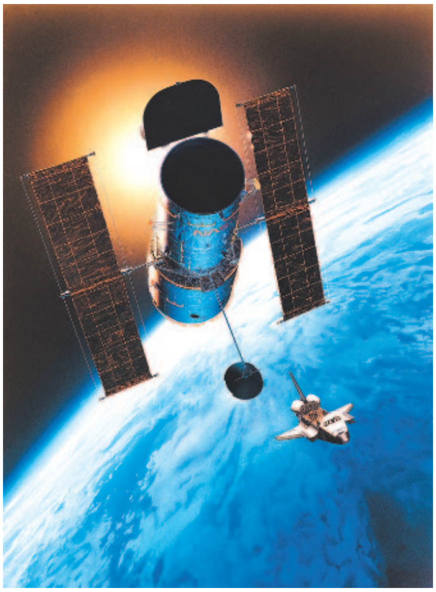
- Use the hand lens to look closely at the print on this page and the tip of your finger.

1. Describe the difference that the hand lens makes to what you see.
2. Draw and label a diagram of a letter 'e' and the tip of your finger as seen through the hand lens.

- Use the hand lens to look closely at a selection of small objects.

3. Draw and label each object as seen through the hand lens.

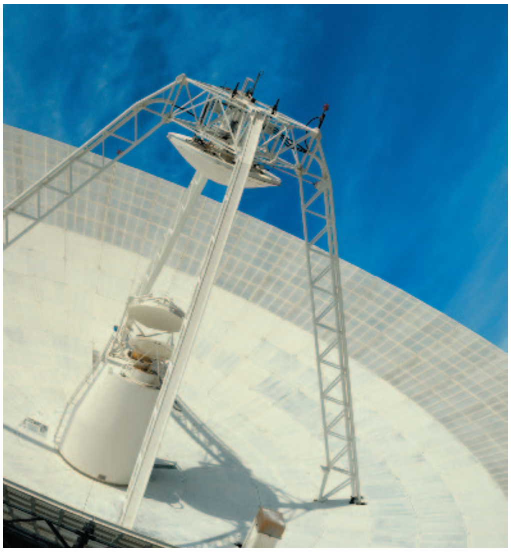
The Hubble, which is both an optical telescope and a satellite, is in orbit about 600 kilometres from the Earth's surface. Its orbit is adjusted each time the space shuttle visits it to repair or upgrade equipment. Hubble has a pair of solar panels to transform the sun's light energy into electrical energy, which then powers all the equipment on board.



The Hubble telescope collects the sun's rays to provide power for its equipment.

Embryonic clouds, forming from clouds of gas, photographed by Hubble telescope

The telescope tube is 13 metres long and 4.3 metres across; an opening at one end of the tube allows light from stars and galaxies to enter. The incoming light is reflected onto a 2.4 metre diameter, curved mirror which reflects the light back towards a smaller secondary mirror. This second mirror focuses the incoming light more and directs it towards a light detector which transforms the light energy into electrical energy. Finally, the energy is transformed into a television signal. A radio dish on the outside of Hubble then transmits this signal back to Earth where it is received and converted into a picture.



Focus point of a radio telescope

Making *light*

Lasers extend our ability to communicate and are used in digital recordings and fibre optics. They produce powerful beams of light. High-energy lasers can cut accurately through metal. In a **laser** (**l**ight **a**mplification by **s**timulated **e**mission of **r**adiation), electrical energy is transformed into light energy. Energy is pumped into one substance called a medium, which can be a solid, liquid or gas. The atoms in the medium get excited by the energy and eventually release light, which is then focused into a laser beam.

The Australian Telescope Compact Array near Narrabri, NSW

Doctor using laser in surgery

An electric light bulb also transforms electrical energy into light energy. The filament in a light bulb is made of tungsten, which is a metal with a very high melting point. When the light bulb is turned on, electricity flows through the tungsten filament. The filament becomes red-hot and emits light. The filament would burn out very quickly if it were allowed to combine with oxygen; to prevent this the bulb is filled with a gas called argon.

Extending *the sense of* hearing

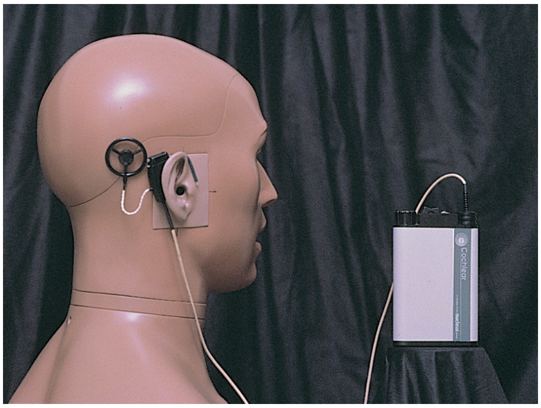
The earliest hearing aids were cone shaped. Modern hearing aids are battery powered and, like the earlier devices, amplify vibrations so that they can reach the cochlea. However, modern hearing aids do this by transforming sound energy into electrical energy. The hearing aid amplifies, or increases, the sound and feeds it into the ear where it is interpreted and sent to the brain via the auditory nerve.

A modern hearing aid

Many people who have severely or profoundly impaired hearing are unable to benefit from hearing aids. Profoundly hearing-impaired people hear no sounds at all.

Australian scientists have developed a device that has allowed some people who are profoundly hearing impaired to detect sound for the first time in their lives. The **cochlear implant**, or **bionic ear**, shown below, is surgically placed inside the ear.

A receiver is attached to the mastoid bone of the skull via a small hole drilled by the surgeon. The surgeon also places electrodes in the cochlea in the inner ear. This amazing invention allows sound energy to be transformed several times before it is finally fed through to the brain via the auditory nerve.



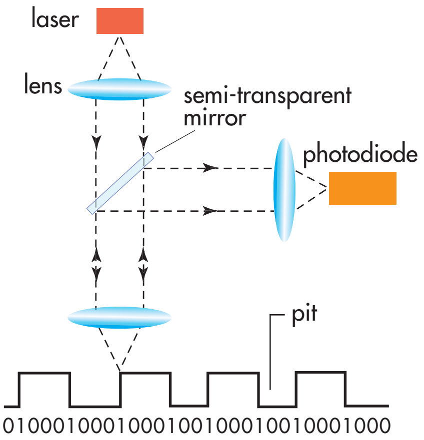
Bionic ear headset and speech processor

Sound waves are first amplified by a microphone in a headset worn outside the ear. They are then sent to the speech processor (a small computer worn in the pocket or on a belt) where they are converted into electrical signals. These electrical signals are sent to the transmitter which converts them into radio waves. The receiver picks up the radio waves and converts them back into electrical signals that are sent to the electrodes within the cochlea. These electrodes stimulate the auditory nerve sending the electrical or nerve impulse to the brain.

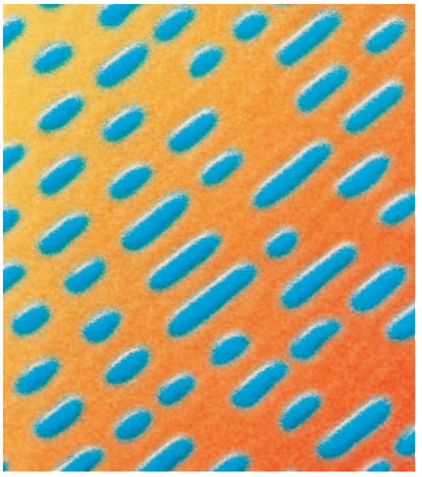
Storing *sound*

A compact disc or CD allows us to listen to our favourite sounds whenever we like. Sounds are stored digitally on a compact disc. To do this, sound is first transformed by a microphone into an electrical signal. This signal is then transformed into a digital code called a binary code, which is made up of ones and zeros to represent the same sound heard by the microphone. On a compact disc, the zeros become little pits and the ones are the smooth bits on the surface. All codes produced by the sound are laid down on the compact disc in a huge spiral several kilometres long.

To retrieve the information on the CD, an optical reader decodes the tracks, turning them back into voltages and then into sounds. The optical reader uses a system of mirrors and lenses to direct a laser beam at the tracks. When the laser beam hits a smooth surface, it is reflected onto a photodiode, which converts the light to an electrical signal. When the laser beam hits a pit, there is no reflection and so no signal. This produces a series of on-off electrical pulses like the ones that were created when the sound was originally recorded on the CD.



When the laser beam detects a pit edge, it is reflected back to the photodiode to produce a '1'.


The surface of a CD is a very long spiral of pits.

Television uses sound and light energy together.

Sound *and light* together

Television uses sound and light technologies together. A television station is assigned a specific channel or radio frequency on which to send its programs out to its audience. Both sound and light energy are transmitted on radio waves. At your home, an antenna or receiving dish picks up the radio waves. It sends them to other equipment in your television which transforms the radio waves back into the sound and vision that was recorded in the studio. Lots of energy transformations allow this to happen smoothly.

Experiment 9.13

MAKING IT SEEM LOUDER

YOU WILL NEED

a ticking watch
metre ruler
sheet of paper, about A4 size
blindfold

- Have your blindfolded partner sit on a chair. Hold a ticking watch close to your partner's right ear. The left ear should be covered with an open palm.
- Move slowly away until your partner indicates that the sound of the ticking watch can no longer be heard.
- Measure and record the approximate distance from the watch to your partner's right ear.
- Make a funnel with a sheet of paper. Place the narrow end of the funnel close to, but not touching, your partner's right ear. Your partner should be able to hold it in place.

CAUTION: Take care not to put the cone into the ear canal.

- Again, move the ticking watch slowly away from your partner, starting near the end of the funnel, until it can no longer be heard. Measure and record the approximate distance between the watch and your partner's right ear.

1. What difference does the funnel make?
2. How does the funnel work?
3. Look at your own ears. Why do you think they are that shape?

Activities

Remember

1. In what devices are lenses used to extend the sense of sight?
2. Explain what the bionic ear is and how it works.
3. Explain how either light or sound can be transformed into different forms of energy.

Think

1. Telescopes and microscopes both use lenses to extend the sense of sight. They are, however, used for different purposes. What is each of these devices used for?
2. A compact disc stores our favourite music. Explain how this is achieved.

Investigate

1. Find out who Helen Keller was and why she became famous.
2. Why was the work of Edwin Hubble so important?
3. Find out about the positive and negative impacts of the invention of the cochlear implant.

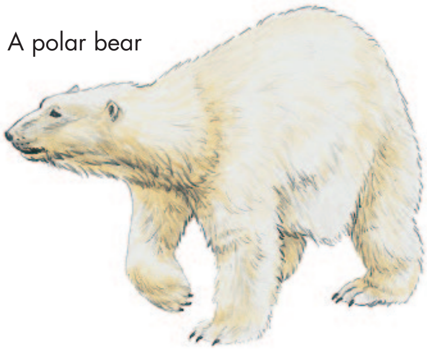
9.8 Ears, eyes and more

There is an amazing variety of ears and eyes in the animal kingdom. An animal's ears and eyes must be suited to where it lives, how it finds its food and how it protects itself from predators.

Hey, *big ears!*

Animal ears generally serve two purposes. They detect sounds and keep balance. Animals that live in hot climates often have ears that help keep them cool. Large ears expose a lot of skin to the air. This allows heat to escape from the animal's body into the air. The desert fox shown below does not sweat. If it did, it would lose too much water. It keeps cool with its large ears. The polar bear also shown below, on the other hand, has very small ears. It needs to keep its body warm and would lose too much heat from big ears.

A polar bear



A desert fox

The size of its ears can be important to an animal's survival in hot and cold climates.

The African elephant's ears enable it to hear low-pitched sounds from other elephants over four kilometres away. They also use their giant ears to release heat, sometimes flapping them to cool down more quickly.

Mammals are the only animals with auricles. Auricles are the fleshy flaps on the outside of the ear.

The African elephant's big ears are not just for hearing.

Eyes *in the* dark

Animals that sleep during the day and are active at night are called **nocturnal** animals. The possum and tarsier are examples of nocturnal animals, as is the owl. Each of these animals searches for food in the dark. Their eyes need to be able to detect the limited amount of light that is available. Many of these animals have big eyes with very large pupils. The pupils are the holes that allow light to pass through the eye to the retina.

Not all nocturnal animals have large eyes. Many have very well developed senses of hearing, smell or touch to make up for the lack of light. They often have large ears or whiskers. The bilby, also known as the rabbit-eared bandicoot, has poor eyesight but survives well at night due to its keen senses of hearing and smell.

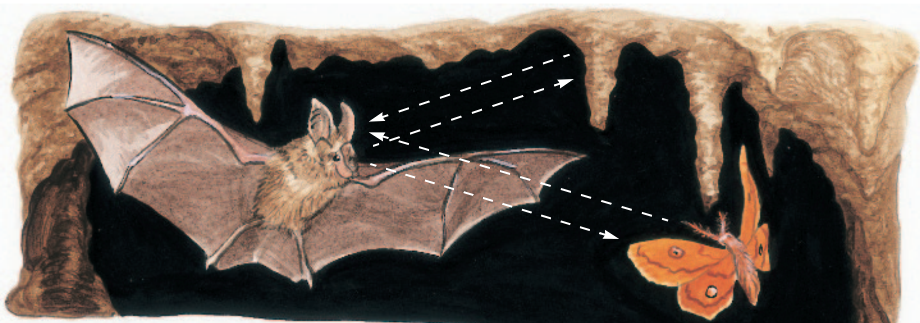
A tarsier

Nocturnal animals often have big eyes with large pupils.

An owl

Looking *for an* echo

Animals such as bats, whales, dolphins, porpoises and some cave-dwelling birds survive well in the dark without large eyes by using **echolocation**. These animals make high-pitched sounds and listen to the echoes of the sounds as they bounce off objects. Bats living in caves emit short bursts of high-pitched clicks as they fly in the dark, searching for their insect prey. Their large ears move as they fly and detect echoes caused when the sounds bounce off insects or obstacles, such as cave walls.



Bats use echolocation to find their food.

Eyes *and* ears *in the* deep

Whales, dolphins and porpoises benefit from using echolocation because of the lack of light under the water. They are able to use the echo from their high-pitched clicking sound to detect schools of fish. They can even tell the size of each fish using the echo. Fish that live more than 100 metres below the surface of the water are in almost total darkness. Many of them have large eyes. Others have a well developed sense of smell. Some, like the angler fish, shown on page 180, take advantage of the darkness by emitting light to attract their prey.

The marine hatchetfish emits a greenish-blue light from organs on the lower parts of its body. The light does not help the hatchetfish to see because it is capable of looking only upwards. It makes it invisible to its predators swimming below. The greenish-blue light is just like the dim light coming from the ocean surface.

Insect eyes *and* ears

Insects have **compound eyes**, made of up to 10 000 tiny lenses. Each lens gives the insect a view of only one direction. All the views together give the insect a total image. While insects do not see the amount of detail in objects that we do, their compound eyes allow them to detect movement easily.

Some insects have ears but they are not on their heads. The ears are membranes like eardrums on the surface of their bodies. A cricket has an ear just below the knee of each of its front legs. A grasshopper has an ear on each side of its body just below the wing. Most insects, however, do not have ears but detect vibrations with sensitive hairs on their antennae or other parts of their bodies.

Activities

Remember

1. Why does the desert fox have such large ears?
2. What are auricles?
3. Why do many nocturnal animals have very large eyes?
4. Explain how bats that live in dark caves find their food and avoid flying into the rock walls.

Think

1. Possums have large whiskers. Why are these important to the possum at night?
2. The tarsier, a small mammal that lives in the tropical rainforests of South-east Asia, has very large pupils. Photographs of the tarsier taken at night often show smaller pupils (see photograph opposite). Why?
3. Rabbits have eyes on the sides of their heads rather than in front. What advantage does that give them?

Investigate

1. Find out how snakes detect sound.
2. Find two examples of technologies that use echolocation. Explain the benefits the technologies have on our lifestyle.

Enlarged view of the head of a dragonfly

Putting it all together

Summing up

Copy and complete the statements below to compile a summary of this unit. The missing words can be found in the word list below.

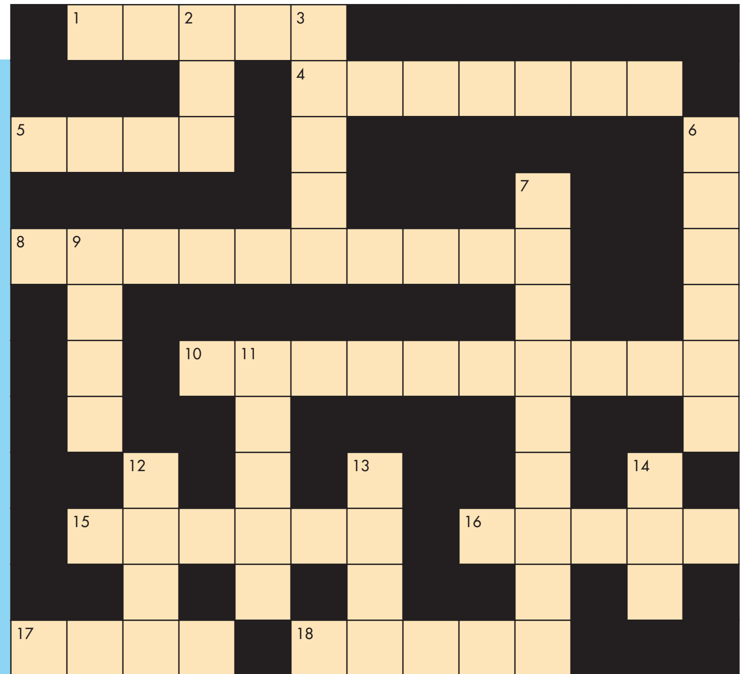
1. Objects that emit light are said to be ______________.
2. Most things that you see are not luminous but ______________ light into your eyes.
3. Images form in ______________ because light is reflected from their smooth surface.
4. ______________ mirrors produce different images from flat mirrors.
5. All sounds are caused by ______________.
6. Sound is a form of ______________ which needs a medium to travel through.
7. The rate at which vibrations occur determines the ______________ of the sound that they cause.
8. Sense organs contain ______________ that respond to a stimulus.
9. Messages are mostly sent from sense organs to other parts of the body through the ______________.
10. The receptors in the eye respond to ______________.
11. The eye produces an image of what you look at by focusing light on the ______________.
12. Vibrations of air are transferred by the eardrum to the ______________ and inner ear.
13. Eyes and ears are very sensitive and need to be treated with great ______________.
14. The sense of sight can be extended with telescopes and ______________.
15. An impaired sense of hearing can often be extended with hearing aids or cochlea ______________.
16. The power of a radio telescope is limited by the size of its ______________ .
17. Modern technology is able to ______________ different types of energy from one to another in equipment we use every day.

Word list

reflect	curved	receptors	pitch
light	care	mirrors	middle
luminous	microscopes	brain	transform
implants	vibrations	retina	energy
dish			

Looking back

1. Complete this crossword, using the clues provided.



Clues

Across

1. The taste of sugar
4. The thin flap of skin at the entrance to the ear
5. The taste of vinegar
8. Used to view organisms too small to see with the eye
10. This is the pathway from the eye to the brain (two words).
15. Images are formed on this surface at the back of your eye.
16. These receptors share their name with a crunchy food item in which ice-creams are sold.
17. The sense organ for smelling
18. This is received on the retina but can also be seen on a TV screen.

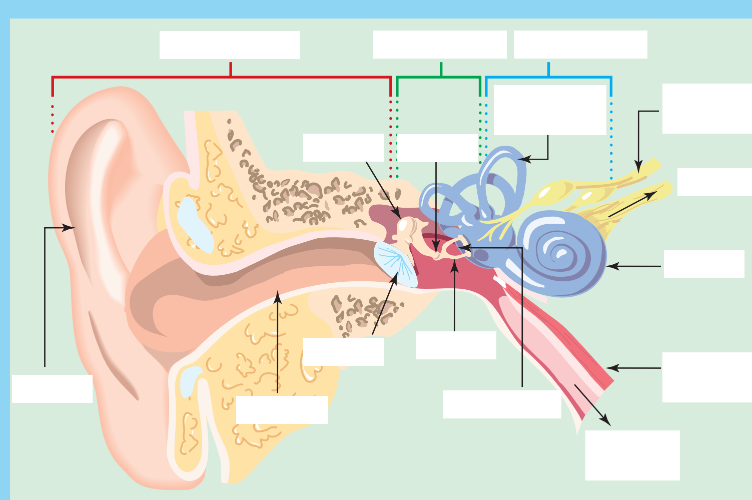
Down

2. An organ for hearing
3. These keep the eye free of dust and also appear when you peel onions.
6. The curved outer part of your eye
7. Used to view distant objects
9. The ring of muscle that gives your eye colour
11. You are one of these and have two of these.
12. A clear, jelly-like object in the eye that brings light to a focus
13. A stimulus that is not quite hot
14. You are unable to do this with both eyes closed.

2. Copy the table below into your workbook, and add the missing information.

Sense	Sense organ	Receptors	Stimulus
		special cells called cones and rods	
	ear		
touch		separate receptors for each type of stimulus	
	tongue		sweet, salty, bitter and sour substances
smell		olfactory nerves	odours

3. Explain how hitting the skin on a drum makes a loud sound. Make sure that your explanation includes the words *vibrate, air* and *louder.*
4. Copy the diagram of the ear into your workbook and fill in the missing labels.
5. Why is a hearing aid of no use at all to some hearing-impaired people?
6. Why do elephants have such big ears?
7. Use the diagram to explain how the cochlear implant would be inserted into the ear. Explain how it can transform sounds and transmit them so that the person can hear.



Extension

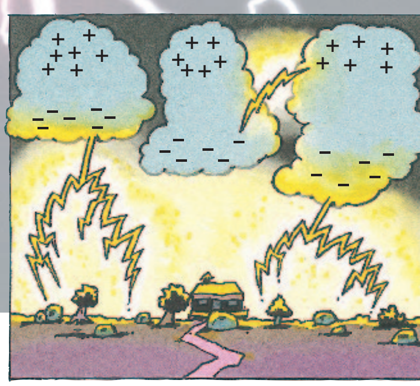
Flash, crash, boom!

During a storm you see flashes of lightning and later you hear thunder. Lightning is a giant electric spark moving between clouds and the ground or other clouds.

In the experiment below, rubbing the ruler causes it to become 'charged', so that the number of 'positively' charged particles in the ruler is different from the number of 'negatively' charged particles. Opposite charges are attracted to each other. The charged particles in the ruler attract the oppositely charged particles in the paper using an electrostatic force often called static electricity. Removing a synthetic jumper quickly causes a build-up of either positive or negative charges. In the dark, you see sparks which are the energy released when the charges move to neutralise each other.

Similarly, fast-moving clouds in a storm become polarised; the top part of the cloud becomes positively charged and the bottom becomes negatively charged. The negatively charged particles are attracted to the positively charged particles in other clouds or the ground. In an electrical storm, so much negative charge is built up that it moves as a giant spark through the air.

The flash of lightning heats up the air around it to temperatures of up to 30 000°C. The hot air expands, its particles crashing into the surrounding cold air particles. Thunder is the noise created by the crashing particles.



Unbalanced charge moves from cloud to cloud or from a cloud to the ground.

SCIFACTS

An average of two Australians each year are killed by lightning. During an electrical storm, you need to take steps to reduce your chances of being struck by lightning. They include the following:

- Do not shelter under a tree.
- Do not stand in any open area. If you are stranded, make sure that you are not the highest object.
- Stay out of and away from water. That includes washing dishes or having a bath near a window.
- Remain in a house, building or fully enclosed vehicle.
- Do not use a telephone except in an absolute emergency.

Experiment 9.14

CHARGING IT UP

YOU WILL NEED

plastic pen
small pieces of paper

- Rub a pen vigorously on your shirt, jumper or blazer and use it to try to lift a small piece of paper from your workbench.

1. Would the pen lift the paper before it was rubbed?
2. What type of force lifts the paper?
3. What are the two forces acting on the paper as it is lifted?

Activities

Remember

1. Explain how clouds become charged.
2. What is thunder?

Think

1. Why do electrically charged particles move from one cloud to another or to the ground?
2. Thunder and lightning actually happen at the same time. Why do you always hear the thunder after you see the lightning?
3. Explain why you should avoid sheltering under a tree during an electrical storm.
4. Why is there no spark when you place a charged plastic pen near a small piece of paper?

Create

Design a poster to warn people how to avoid being struck by lightning in an electrical storm.

Reflection

1. Mind map revisited

GROUP WORK

(a) Revisit the list of words and mind map that you made with your group or partner about your eyes and ears. Write meanings for the words on your list. Update the mind map by correcting any errors and adding your new understandings.
(b) Redraw your mind map on your own to see how much you remember. When you run out of ideas, look at your original mind map to get started again. Practise until you can redraw it from memory.
(c) Now try and draw a mind map to cover everything you have learnt while studying this chapter. You will need a large sheet of paper!

2. Music

Listen to your favourite piece of music. Try to identify all the different sounds you can hear. For each individual sound, describe what is vibrating to make the sound and how the pitch is changed.

3. Surveying

Conduct a survey to see what people know about their senses.
(a) Write a short explanation about conscious responses and reflex actions (describing how each one works). Then make a list of mixed examples of both conscious responses and reflex actions.
(b) Read the explanation and the list to the people you are surveying, and ask them to decide if each example is a conscious response or reflex action.
(c) Collate your responses and make a conclusion about what your survey results told you.
(d) How could you improve the way you present your survey so that all respondents understand the differences between reflex responses and conscious actions?

4. Making models

GROUP WORK

Make a model of an eye or an ear and label all the parts. Present your model to the class and explain how it works.

5. Avoid losing your senses

Sometimes, we lose the power of our eyes or ears because we do not take simple precautions. Make a poster reminding people about possible dangers to eyes or ears, including hints on how to prevent them from being damaged.

Experiment 9.15
Measuring the speed of sound

YOU WILL NEED

2 garbage lids	earmuffs
trundle wheel	stopwatch
a partner	

- Have one person (the noise maker) put on the earmuffs and hold the lids.
- Move to a position about 350 m (measured with the trundle wheel) from the noise maker.
- Signal to the noise maker to bang the lids hard over his or her head.
- Start the stopwatch once you see the lids come together and stop it once you hear the noise. Write down the time shown on the stopwatch.
- Repeat your experiment several times and average your results. Use the formula

  $\text{speed} = \frac{\text{distance}}{\text{time}}$ to work out the speed of sound.
- Prepare a report outlining your experiment and comment on how your results compare with the real value.

How would you work out the speed of sound in water? Would you expect it to be higher or lower than the speed of sound in air?